

ABSTRACT

“Mobile Phone Microscope Imaging for e-health Applications at Low Resource Setting; Image Processing for Automatic Counting of Blood Cells”

BACKGROUND: The purpose of this study was to design portable mobile phone microscope imaging (PMPMI) device for e-health application in low resource settings to enabling the health extension workers (HEW) or community health workers (CHWs) promote early detection and protection of diseases by means of automatic complete blood cell (CBC) count

METHODS: Design and assembling the mobile attachment microscope; develop web page and upload the clinical laboratory atlas; apply image sharing apps and develop mathematical algorithm for automatic CBC count

RESULTS: the proposed mobile phone microscope imaging device is able to share sample images with next level lab technologists/pathologists via image sharing open applications and the developed image processing scheme allows *automated complete blood cell* (CBC) count on images acquired through the *new coupled system*. The counting algorithm offered an overall effectiveness of 90% in RBC count and 99.9% in WBC count. Additionally, a web site is developed to upload the lab-atlas images for further reference.

CONCLUSIONS: The new coupled mobile phone-microscope device functions in white light settings. The work promotes early detection and protection of diseases and presented here as a cost-effective option. The device has been designed in such a way that it could be used not only by health extension workers (HEWs) but also by the higher-level Hospital laboratory personals. The effectiveness of the developed cell counting algorithm could show the great promises of the proposed imaging system.

Keywords: *mobile phone Microscope, Health Extension Worker (HEW), Tel-laboratory, e-health, website, atlas, Complete Cell Count (CBC), Mathematical Algorithm.*

Introduction

In the LIC there is no remote follow-up of cancer patients taking treatments (chemo/radio-therapy); early detection of infections and anemia diagnosis; no simple technology is develop to promoting early detection and protection of malaria and TB epidemics, and to treatment monitoring for anemia and other blood diseases. This study also reduces the ergonomic effect and human errors such as the Ergonomic effect as headaches, shoulder pain and back pain demonstrated on almost 70% of the clinical lab technologists, who are working on analog microscope examination procedure. More than 30% of the clinical lab technologists also suffer from legs, feet, wrists, hands and fingers pain.

Table 1: Percentage of Medical Problems Reported by Microscope Operators [Source: microscope.com]

Anatomical Location	Employee Percentage
Neck	50-60
Shoulders	65-70
Back (Total)	70-80
Lower Back	65-70
Lower Arms	65-70
Wrists	40-60
Hands and Fingers	40-50
Legs and Feet	20-35
Eyestrain	20-50
Headaches	60-80

This thesis project focuses on the bright field setting. The complete blood cell (CBC) count provides valuable information about the blood. In this thesis, a coupled mobile phone- light microscope imaging device has been designed and developed and an image processing algorithm has been developed for automated CBC application including a web based clinical decision support system. Captured images are manually compared with clinical laboratory specimens-atlas.

Research Objectives

The current project will have important implications in the efforts to alleviate the efficiency of HEWs and the health care referral system (primary-secondary-tertiary) thereby supporting the national e-health strategy that is crucial to achieving universal health coverage (to meet SDG-3).

- The study promotes the safe, equitable and quality of clinical service for low resource settings
- The automated scheme for CBC count is particularly developed for the following purposes:
- Demonstrates Tele-laboratory system

PROPOSED Material and METHOD

The research used the materials and/or methods to meet the objectives and purpose of the research. The first method is design and assembly of mobile attachment microscope to detect diseases from blood sample. The second method is developing web page and uploads the clinical laboratory atlas for further interpretation of the laboratory image result. The last step is developing mathematical algorithm for CBC to count the red and white blood cell from the blood sample.

Mobil microscope

➤ In this thesis, the prototype tested, and it is the innovative technology in Ethiopia which will go on the scale up phase. It uses for both as microscope attachment or replacing CCD digital camera and stand-alone mobile microscope which is designed in cost-effective way.

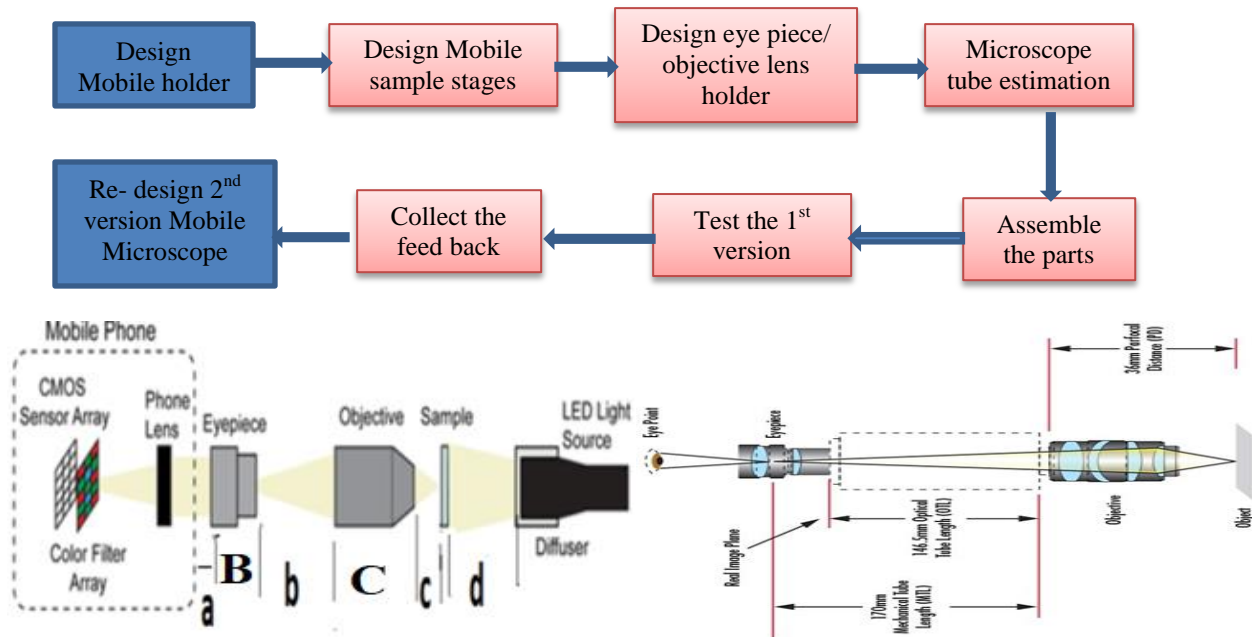


Figure 1. As per JIS standard, in our project the mobile attachments distance [mm] shown below

$$OTL=b=146mm, \quad MTL=B+b=170mm, \quad PO=C+c=36mm, \quad a\sim 1mm, \text{ and } d\sim 12mm(\text{adjustable})$$

Microscope international standards

There are two main microscope international standards: DIN (Deutsches Institutfür Normung) and JIS (Japanese Industrial Standards).

Table 2: Microscope international standards: DIN and JIS

No	Parameters	DIN	JIS	Remark
1	tube length (Eyepiece - objective)	160mm	170mm	Mechanical Tube L.
2	Eyepiece diameter	23mm	23-30mm	
3	Object mean focal distance	45mm	36mm	Parfocal Focal Distance
4	Distance to the eyepiece field	150 mm	145 mm	Optical Tube Length
5	Internal real image from tube	10mm	10mm	
6	Eyepieces diameter	195mm,	195mm,	
7	objectives thread° diameter,	0.7965"	0.7965"	RMS mounting thread
8	Whitworth threading.	36 TPI, 55	36 TPI, 55	RMS mounting thread

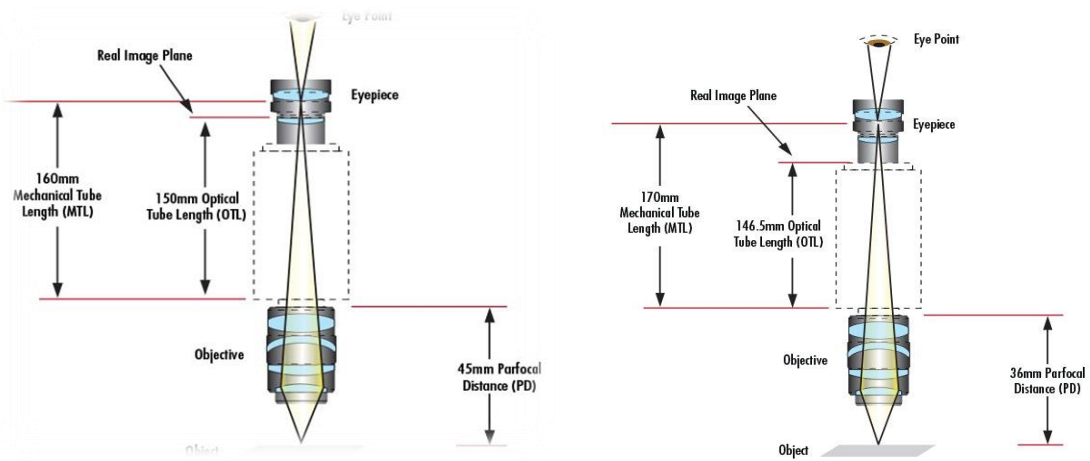


Figure 2. : Microscope international standards: DIN (left) and JIS (right)

- Mobil phone and eye piece holder
- Made of: Plastic

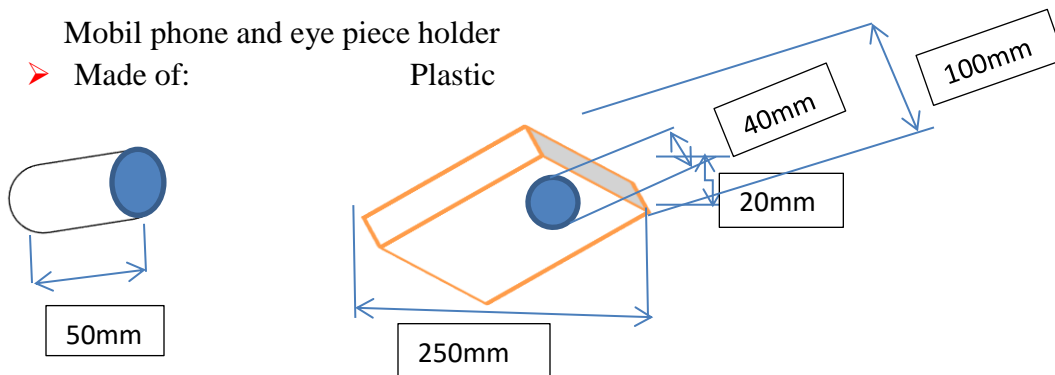


Figure 3. a. Eye piece Holder & Mobile camera Attachment/Holder

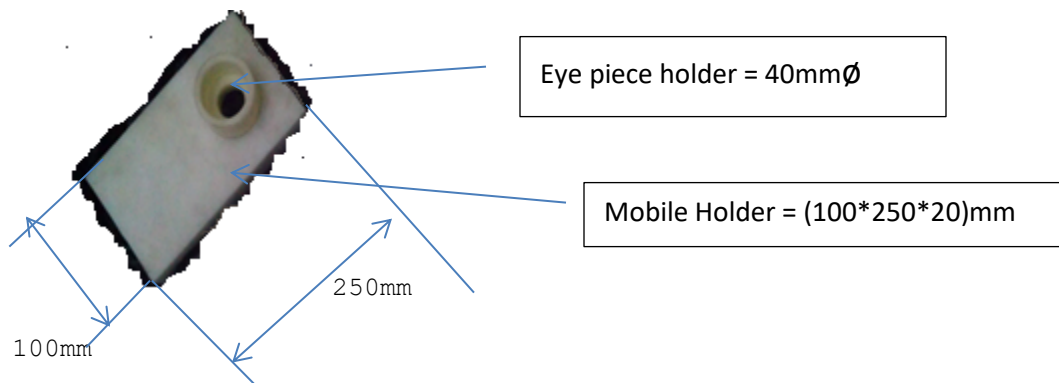


Figure 3. b. Mobile and Eye piece Attachment specification

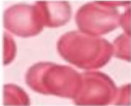

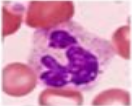

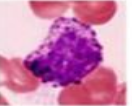
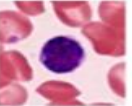

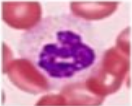

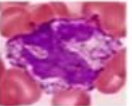
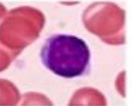

- Tube
- Made of: Plastic
- Tube length: 130mm



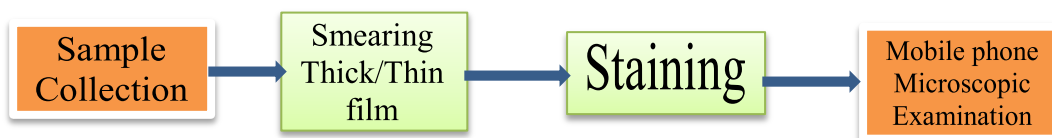
Figure 3. c. Mobile Microscope Tube length

How a CBC test is done in a Clinical laboratory or hospital laboratory.

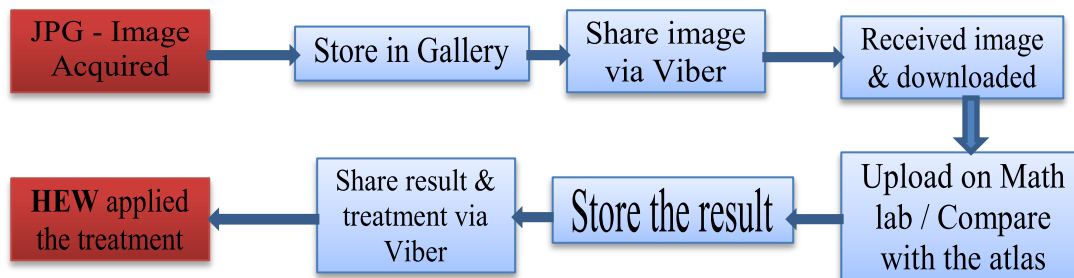
Table 3. CBC test parameters(RBC, WBC and Platelets)

RBC	Platelets	WBC				
Red Blood Cells	Platelets	Neutrophils	Eosinophils	Basophils	Lymphocytes	Monocytes
						
						

Clinical Laboratory for sample preparation procedure



Mobile Networking for tele-medicine and tele-laboratory

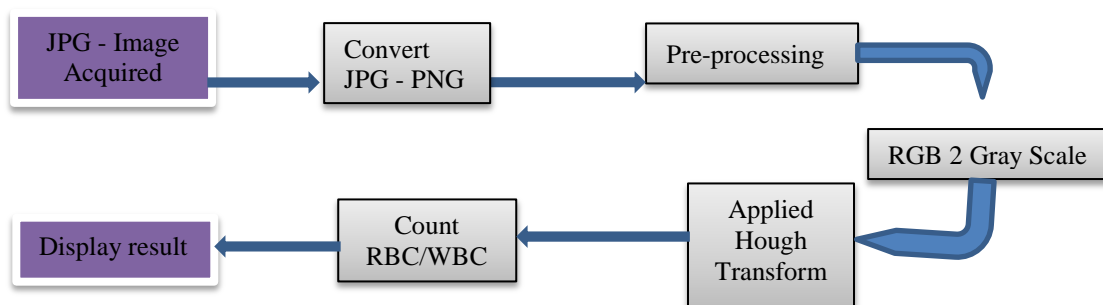


Hough Transform CBC count

➤ Hough Transform Based Methods for CBC count

In this thesis, the circular Hough transform is applied to extract RBCs and WBCs that bring the fast and cost-effective way on blood cell count.

Detailed Image Acquisition and Image Processing



Web development

➤ Our main focused is to setup virtual environment to increase accessibility and availability of device and professionals in LIS. So, it is very valuable in low income countries where there is scares of skilled laboratory technologist

RESULT



Figure 4. a. 1st mobile phone Microscope Assembly. 2nd re-designed mobile Microscope

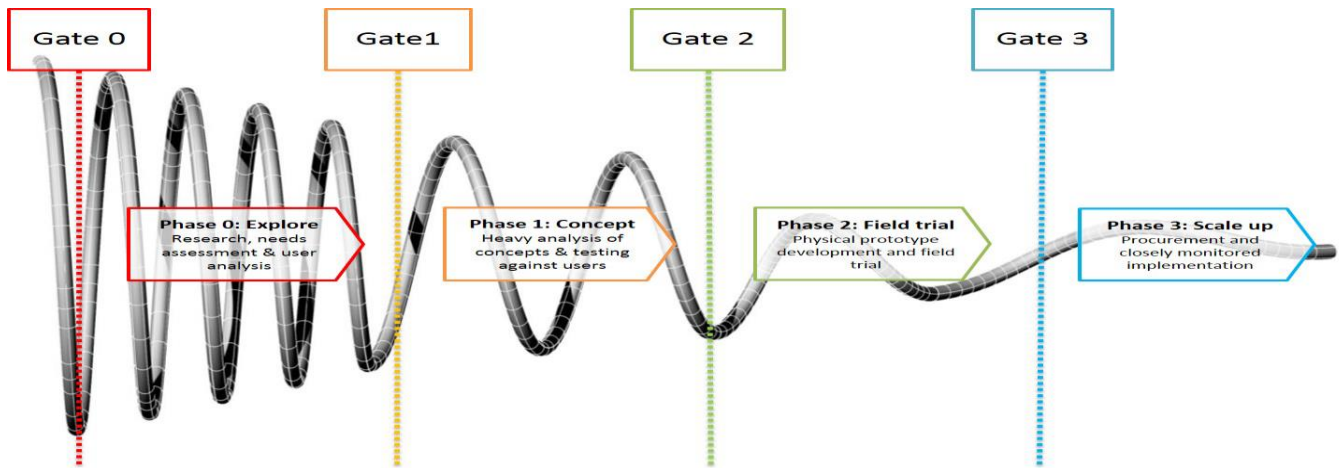


Figure 5 : process for developing product innovation processes (PIPs)

Our prototype is in phase two field trial level. It is successful and need tested in different environment conditions before transfer to phase three or scales up.

Ethical Considerations

The use of patient samples should be approved jointly by the AAU and the health institutions (HSC and Black Lion Specialized Hospital) IRBs. Written information consent should be obtained for all patient samples. The IRB is the decision-making body established to govern all PIPs. From Gate 1 and forward, make all gating decisions. This Project has been approved by IRB (Institute of Review Board)

Table 4: Testing different sample image and interpreted by senior lab technologist in teaching lab.

no	Sample type	Lab unit	Test sample type	result	remark
01	Hematology cell	Teaching lab	Blood	RBC, WBC	
02	Hematology cell	Teaching lab	Blood	RBC, WBC	
03	Bacteriology tissue	Teaching lab	Blood	Not clear	Poor slide
04	Bacteriology tissue 2	Teaching lab	Blood	Not clear	Poor slide
05	Symptoms	Teaching lab	Blood	Acid fast bacilli	

06	Symptoms 2	Teaching lab	Blood	Acid fast bacilli	
07	Hematology parasite	Teaching lab	Blood	Malarial parasites	
08	Hematology parasite 2	Teaching lab	Blood	Malarial parasites	
09	Hematology cell	Teaching lab	Blood	Blast cell immature	
10	Hematology cell 2	Teaching lab	Blood	Blast cell immature	
11	Whole blood cell	Teaching lab	Blood	MM	
12	Whole blood cell	Teaching lab	Blood cancer	AML	
13	Whole blood cell	Teaching lab	Blood cancer	CMML	
14	Whole blood cell	Teaching lab	Blood	Malaria Parasite	
15	Whole blood cell	Teaching lab	Blood	Neutrophil	
16	Whole blood cell	Teaching lab	Blood	RBC blood cell	

Table 5: Validation of the result through comparison with existing hematology analyzer and manual CBC

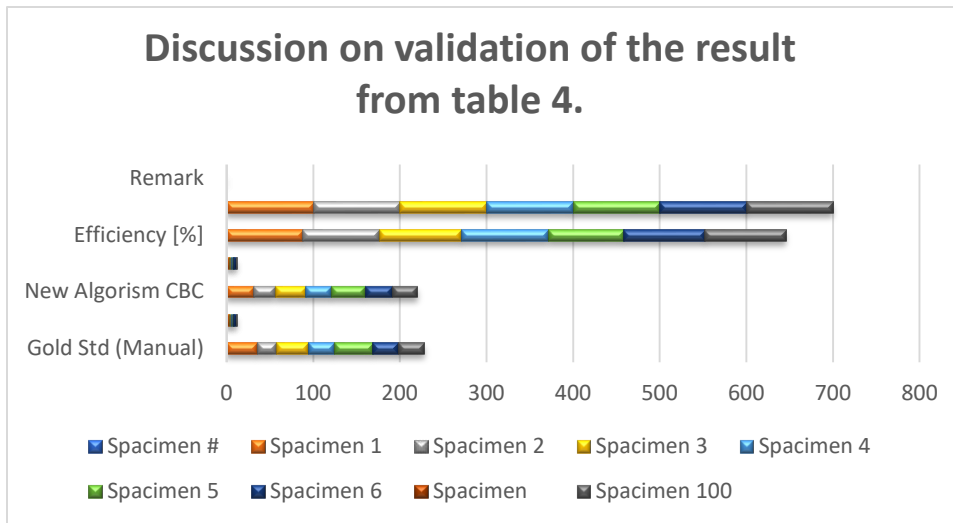
Specimen #	Gold Std (Manual)		New Algorithm CBC		Efficiency [%]		Remark
Specimen #	#RBC in Gold Std	# WBC in Gold Std	#RBC 2	WBC 2	% RBC	% WBC	Remark
Specimen 1	35	3	31	3	88	100	
Specimen 2	22	0	25	0	88	100	
Specimen 3	37	2	35	2	95	100	
Specimen 4	30	2	30	2	100	100	
Specimen 5	45	1	39	1	87	100	
Specimen 6	29	3	31	3	94	100	
Specimen
Specimen 100	30	1	29	1	94	100	



DISCUSSION ON RESULT, SOME LIMITATION and CHALLENGE

With the increasing acceptance of a mobile phone as a sensing and health tool, however, an opening of the camera toolkit for biomedical applications would have a significant impact.

Discussion



The result of our design prototype and the selected algorithm for CBC counting has a good potential to be the candidate of the current merged technology for LRS/LIC. It is fulfilling or met target of the project. It is validated with gold standard as shown below.

Figure 6. The result Validated by comparing with manual CBC count.

LIMITATION

- The sample collection is varied based on skill and commitment of the expert
- Preservation and despatch of the sample was poor.
- The Atlas automated Mobile application software (AI via python) is Not yet developed
- It works for piloting but not the full-fledged as Medico legal on clinical trial practices
- Additional fund is needed for improvement and scale up for real world application

CHALLENGE

- Blood specimens stored at room temperature for more than 1 day (up to 3 days or possibly longer) were found to be acceptable with some limitations for CBC but not for the differential.
- The project took longer time to be feasible or to reach as this level.
- Poor blood sample collection and preparation in both (thin and thick) film. More than 3000 are collected but 90% of the sample is not clear. Only 10% is effective to use in this project.

CONCLUSIONS and RECOMMENDATION

CONCLUSIONS

Once the device installed it can easily identify malaria and other blood parasite which was invisible with the naked eye and which is difficult to detect from microscope by the less skilled lab technician.

- For referral and University Hospitals the device uses as the teaching purpose by interface with monitor and Microscope.
- For General Hospitals the device uses as the replacement of CCD camera LIS
- For primary hospital and health center it can be used to get referral professional skill support
- For HEW which highly support and strengthening the homecare service. That increase accessibility, availability, **Equity and quality** of healthcare service.

Moreover, *it prevents the risk of operators, reduces human errors and Percentage of Medical Problems Reported by Microscope Operators in high level Hospital's Laboratories (see in table 1).*

The new device is clinically Valid, Cost effective, Flexible and simple technology

- **Clinically Validated:** Validation Testing on over 300 blood samples from different healthcare facilities yielded more than 90% correlation to a Lab-technologist's diagnosis
- **Flexible & Simple Technology:** Flexible & simple design to attach the mobile phone with microscope parts. Uses as point of care portable devices
- **Cost Effective:** Improve healthcare outcome at a lower cost than the existing technologies. We focused on affordability, availability and accessibility

RECOMMENDATION and FUTURE WORK

This device is leading as a benchmarked in m-health local production and technology transfer project. It can simply be converted in to Blood chemistry machine in the clinical laboratory. It should be supported to be local production that enables to save life and encore foreign currency. Scaling up of this technology in innovative way helps the low resource setting to meet the United nation sustainable development goal (UN-SDG) 3, 14, 15 and 17

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